MEASUREMENTS OF THE UNDERWATER ACOUSTIC AMBIENT NOISE IN THREE LARGE TANK EXHIBITS AT THE MONTEREY BAY AQUARIUM

Steven R. Baker, Associate Professor
Department of Physics
Sponsor: Unfunded

OBJECTIVE: To measure the underwater acoustic ambient noise in the three large tank exhibits at the Monterey Bay Aquarium, and to compare these measurements to underwater ambient noise measurements made in the Monterey Bay.

SUMMARY: Measurements were made of the underwater acoustic ambient noise in three large tank exhibits at the Monterey Bay Aquarium: the Kelp Forest Exhibit (335,000 gal), the Monterey Bay Habitats Exhibit (350,000 gal), and the Outer Bay Waters Exhibit (1.4 million gal). A single, calibrated, Navy type DT-276 was used. The hydrophone output voltage was preamplified and recorded using a 16-bit digital audio tape recorder, with a sampling rate of 48 kHz. Measurements were made with various mechanical equipment (motors, fans, pumps, sprinklers, wave machine) turned on and off. On one occasion, the noise was measured in the largest tank, the Outer Bay Waters Exhibit, during a complete power shutdown. For comparison, measurements were also made at several locations and depths in the inner Monterey Bay. One-third octave band and narrow-band analyses were performed. Comparisons were made between the aquarium and bay results, and standard deep-water acoustic ambient noise spectral density curves.

PUBLICATIONS:

O'Neal, Daniel M. and Baker, Steven R., "Results of Underwater Ambient Noise Measurements in Three Large Tank Exhibits at the Monterey Bay Aquarium," *Proceedings of the 16th International Congress on Acoustics and the 135th Meeting of the Acoustical Society of America*, Vol. II, pp. 1411-1412, 1998.

O'Neal, Daniel M. and Baker, Steven R., "Results of Underwater Ambient Noise Measurements in Three Large Tank Exhibits at the Monterey Bay Aquarium," abstract in *Journal of the Acoustical Society of America*, Vol. 103, p. 2908, 1998.

CONFERENCE PRESENTATIONS:

O'Neal, Daniel M. and Baker, Steven R., "Results of Underwater Ambient Noise Measurements in Three Large Tank Exhibits at the Monterey Bay Aquarium," Joint Meeting of the International Congress of Acoustics and the Acoustical Society of America, Seattle, WA 20-26 June 1998.

THESIS DIRECTED:

O'Neal, Daniel Matthew, "Comparison of the Underwater Ambient Noise Measured in Three Large Exhibits at the Monterey Bay Aquarium and in the Inner Monterey Bay," Master's Thesis, Naval Postgraduate School, June 1998.

DoD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Bioacoustics, Underwater Ambient Noise, Aquarium

NUMERICAL MODELING OF SONAR TRANSDUCERS AND ARRAYS

Steven R. Baker, Associate Professor
Department of Physics
Clyde L. Scandrett, Associate Professor
Department of Mathematics
Sponsor: Office of Naval Research

OBJECTIVE: To continue development of the T-matrix method for the numerical modeling of arbitrarily densely- and randomly-packed sonar arrays. Specifically, the objectives for FY98 were to: (1) obtain the upgraded version of the ATILA finite-element code (for the analysis of sonar transducers) and arrange for it to include the ability to compute the scattering of acoustic waves for arbitrary incidence; (2) refine the mesh of our ATILA model for a fluid-loaded elastic spherical shell and compare the T-matrix elements computed using this model with the results previously obtained using the coarser model and with exact analytical values; (3) collaborate with colleagues at NUWC to compute the T-matrix elements for a transducer of interest using an ATILA model; and (4) continue to investigate the feasibility of coupling an ATILA model for the transducer structure to a specialized code for computing acoustic scattering, with particular attention to the nearfield.

SUMMARY: Objectives 1, 2, and 4 were accomplished. The new version of the ATILA code was upgraded to include the ability to compute acoustic scattering for arbitrary incidence and was ported to Professor Baker's SGI workstation. It was not possible to refine the existing meshes in a sensible way, with the refinement tools built into ATILA, so a new mesh was created. This mesh will be tested and refined in FY99. Three candidate schemes were applied for computing the single-scattering T-matrix to a test problem, that of a thin spherical steel shell in water, and the results were evaluated against analytical results obtained using thin-shell theory. The three were: (1) an ATILA-only method, employing its built-in radiation dampling elements; (2) a method employing only SYSNOISE, a commercial finite-element code for computing acoustic fields; and (3) a method which features ATILA coupled to another code from ISEN, called EQI, for computing acoustic fields. The three methods differ mainly in the way in which the radiation boundary is modeled. From the results, it was concluded that the combination of ATILA coupled with EQI is the most promising for future development of the T-matrix method applied to active sonar arrays. Detailed results are given in the reports listed below.

PUBLICATION:

Scandrett, C.L. and Baker, S.R., "T-Matrix Approach to Array Modeling, Naval Postgraduate School Technical Report, NPS-UW-98-001, October 1998.

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Active Sonar, Transducer, Array, Numerical Modeling, Finite-Elements

SHIP DEFENSE WITH FREE ELECTRON LASERS

William B. Colson, Professor
Department of Physics
Sponsor: Naval Postgraduate School

OBJECTIVE: The free electron laser has a unique pulse format where a sequence of picosecond long pulses may damage materials more efficiently than the more typical cw laser. Research is proposed to study free electron laser damage.

SUMMARY: The free electron laser at Thomas Jefferson National Accelerator Facility has reached a power level of several hundred watts. The power density required for defense against sea-skimming missiles is 10 kW per square centimeter. When the laser is focussed to a spot-size of about one square millimeter, the intensity matches that required for missile defense and represents a fairly large macroscopic area.

PUBLICATION:

Colson, W.B., "Short-Wavelength Free Electron Lasers in 1997," *Nuclear Instruments and Methods in Physics Research,* A407, pp. 26-29, 1998.

CONFERENCE PRESENTATIONS:

Colson, W.B., "Short-Wavelength Free Electron Lasers in 1997," poster presentation, Twentieth International Free Electron Laser Conference, Williamsburg, VA, August 1998.

THESIS DIRECTED:

Herbert, Paul A., "Anti-Ship Missile Defense and the Free Electron Laser," Master's Thesis, December 1998.

PATENTS:

Robinson, Kem E., Gottschalk, Stephen C., Quimby, David C., and Colson, William B., Patent Application Number 08/55,731: "Optical Mode Tapered Undulator and Method for Producing the Same."

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Directed Energy Weapons

KEYWORDS: Free Electron Laser, Industrial Laser Processing

HIGH POWER INFRARED FREE ELECTRON LASERS FOR SHIP DEFENSE

William B. Colson, Professor
Department of Physics
Sponsor: Space and Naval Warfare Systems Command

OBJECTIVE: To research studies of the high average power infrared wavelength free electron lasers at the Thomas Jefferson National Accelerator Facility, Newport News, VA. SPAWAR is developing the technology for using free electron lasers (FELs) to defend ships against sea-skimming missiles.

SUMMARY: NPS is working with Jefferson National Accelerator Facility and SPAWAR to develop the superconducting accelerator technology for a high power laser. The design must meet the requirements for a high-power shipboard laser weapon. During the year, the laser began operation for the first time and developed a power of 500 Watts.

PUBLICATIONS:

Kesselring, M., Colson, W.B., Wong, R., and Sheffield, R.L., "Simulations of the LANL Regenerative Amplifier FEL," *Nuclear Instruments and Methods in Physics Research,* A407, II-23, 1998.

Nguyen, R.T., Colson, W.B., Wong, R., and Sheffield, R.L., "Simulations of a Regenerative MW FEL Amplifier," *Nuclear Instruments and Methods in Physics Research,* A407, II-3, 1998.

CONFERENCE PRESENTATION:

LeGear, R.E., Steele, R.B., McGinnis, R.D., and Colson, W.B., "Simulations of the Proposed TJNAF 20 kW Free Electron Lasers," poster presentation at the Twentieth International Free Electron Laser Conference, Williamsburg, VA, August 1998.

THESES DIRECTED:

LeGear, R. Eric, "Simulations of Proposed 20 kW Klystron Free Electron Laser," Master's Thesis, June 1998.

Steele, Richard B., "Simulations of Proposed TJNAF 20 kW Free Electron Laser," Master's Thesis, June 1998.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Directed Energy Weapons

KEYWORDS: Free Electron Laser, High Energy Laser

PARAMETRIC EXCITATION

Bruce Denardo, Associate Professor
Department of Physics
Sponsor: Office of Naval Research

OBJECTIVES: To excite a sound mode in a gas-filled resonator by parametric excitation (modulating a parameter upon which the resonance frequency depends). When this occurs in any oscillator, the response amplitude grows exponentially until it is saturated by a nonlinearity of the system. Hence, large response amplitudes may be possible. Another goal was to determine the mechanism that saturates the growth. If large amplitudes can be obtained, this research may lead to the use of parametric drives in various practical devices such as thermoacoustic refrigerators, acoustic compressors, acoustic pumps, and intense underwater sound sources. In a related project, the goal was to perform experimental, analytical, and numerical investigations of the newly-discovered parametric instability of a general system of two weakly coupled nonlinear oscillators.

SUMMARY: Parametric excitation was attempted for a double Helmholtz resonator (two cavities connected by a neck) for two different types of drive. In the first case, the neck was constructed to be similar to a trombone slide, so that the neck length could be modulated by a shaker. The maximum drive amplitude was not expected to exceed the threshold condition for excitation, but the experiment was pursued to observe whether the effective quality factor of the mode increased with increasing parametric drive amplitude, according to the theory. Surprisingly, the quality factor *decreased*, which was found to be the caused by turbulence. In the second system, the cavity volumes were modulated by pistons. This drive was predicted to exceed threshold, but parametric excitation did not occur. The reason for this is currently being sought. In the coupled-oscillator project, a finite-amplitude instability of one of the normal modes of a system of two weakly coupled nonlinear oscillators was determined to be caused by the mode parametrically driving the other normal mode, which is stable. The investigations yielded an understanding of the behavior, some of which was surprising. For example, natural qualitative reasoning leads to the conclusion that the stable mode should be unstable and the unstable mode should be stable.

PUBLICATIONS:

Prather, Wayne E., Denardo, Bruce, and Raspet, Richard, "Parametric Excitation of a Helmholtz Resonator," *Journal of the Acoustical Society of America,* Vol. 103, No. 5, Pt. 2, p. 2765, 1998.

Denardo, Bruce, Earwood, John, and Sazonova, Vera, "Parametric Instability of Two Coupled Nonlinear Oscillators," *American Journal of Physics*, 1999, to be published.

CONFERENCE PRESENTATION:

Prather, Wayne E., Denardo, Bruce, and Raspet, Richard, "Parametric Excitation of a Helmholtz Resonator," Acoustical Society of America, Seattle, WA, 20-26 June 1998.

DoD KEY TECHNOLOGY AREAS: Other (Acoustical Resonators, Nonlinear Oscillations)

KEYWORDS: Parametric Excitation, Instability, Nonlinear Oscillations

SOLITONS
Bruce Denardo, Associate Professor
Department of Physics
Sponsor: Office of Naval Research

OBJECTIVE: To theoretically and experimentally investigate the possibility of generating solitons (self-localized nonlinear waves that act as particles) in a bar of sandstone. An observation of a soliton in rock would be the first of its kind. In another project, the goal was to experimentally investigate mode hopping for an annular channel of water with parametrically driven surface waves. The transition of one standing wave mode to another in this system involves a localized kink soliton.

SUMMARY: New types of solitons solutions were discovered for a class of systems with nonanalytic nonlinearities. (A *nonanalytic* function has a discontinuity in the function or any derivative of it.) The unusual behavior of the frequency of compressional standing waves in sandstone as a function of amplitude allows this medium to be modeled with a nonanalytic nonlinearity. Similar behavior occurs for clocks with flexible pendulums interrupted by sandwiched circular disks, which were experimentally investigated by Huygens in the 1600s. Nonanalytic soliton solutions for sandstone were obtained, and the experimental generation of these solitons was determined to be feasible. Experiments were performed, but the solitons could not be generated due to various complications, including the mode structure being complicated by shear waves. In the mode hopping project, the behavior of the up-hopping and down-hopping instabilities was mapped in the plane of drive amplitude vs. drive frequency. The low-amplitude data was fit by Mathieu curves.

PUBLICATION:

Denardo, Bruce, "Nonanalytic Nonlinear Oscillations: Christiaan Huygens, Quadratic Schrödinger Equations, and Solitary Waves," *Journal of the Acoustical Society of America,* Vol. 104, pp. 1289-1300, 1998.

DoD KEY TECHNOLOGY AREAS: Other (Solitons)

KEYWORDS: Solitons, Nonanalytic Nonlinearity, Mode Hopping

ELECTRICAL RESISTIVE NETWORKS
Bruce Denardo, Associate Professor
Department of Physics
Sponsor: University of Mississippi

OBJECTIVES: To perform experiments and numerical simulations of several types of large electrical resistive networks and to compare the results to the existing theories. Electrical networks are useful as an augmentation of an Ohm's law experiment in the educational laboratory and as lecture demonstrations. In addition, the work has applications to modeling for geophysical exploration with electrical currents and to petroleum flow in oil wells.

SUMMARY: Two resistive networks were considered. In the first, the equivalent resistance was measured across the ends of a ladder whose number of loops was incremented until the precision of the ohmmeter was exceeded. In the second, resistances were measured across nodes near the center of a 12 by 12 square grid of resistors. In the ladder experiment, the approximate exponential decrease in current in successive loops had several important consequences. In the square grid experiment, the algebraic decrease in current with distance from the ohmmeter terminals similarly had important consequences. The square grid results gave approximate confirmation of complicated theoretical calculations for the equivalent

resistance across two nonadjacent nodes of an infinite square lattice. The experimental results were verified numerically by a relaxation method and alternatively with commercial software.

PUBLICATIONS:

Denardo, Bruce, Earwood, John, and Sazonova, Vera, "Experiments With Electrical Resistive Networks," *American Journal of Physics*, 1999 to be submitted.

DoD KEY TECHNOLOGY AREAS: Other (Educational Physics, Geophysical Exploration and Oil Flow)

KEYWORDS: Electrical Networks, Equivalent Electrical Resistance, Ohm's Law

DETECTION AND CLASSIFICATION OF CHEMICAL AND BIOLOGICAL AGENTS

Robert C. Harney, Associate Professor
Department of Physics
Sponsor: Naval Postgraduate School

OBJECTIVE: To determine the feasibility through analyses and component demonstrations of developing a sensor for the remote detection and classification of chemical and biological warfare agents using a frequency tunable ultraviolet laser in a spectroscopic Raman lidar system.

SUMMARY: A strawman system concept has been developed for a Raman lidar system adaptable to detecting and classifying chemical and biological warfare agents. A moderate-prf, pulsed ultraviolet laser would be scanned over the scene of interest. Returns from the scene would be optically filtered to remove reflected laser radiation, leaving only wavelength-shifted signals due to fluorescence and/or Raman scattering, which would be detected by fast photon counting electronics. Such signals are strongly indicative of contamination by biological (mostly fluorescence) or chemical (usually Raman scattering) aerosols or films. Upon detection of sufficient contamination to warrant classification, the lidar will be electronically reconfigured to transmit alternate longer- and shorter-wavelength ultraviolet pulses in a fixed direction. The returns for each transmitted wavelength will be spectroscopically analyzed, detected, and separately recorded. After sufficient observation time (seconds?) the two spectra will be subtracted (this process eliminates much of the fluorescence signal, leaving an enhanced Raman signal. The Raman signal will be analyzed using traditional spectral analysis algorithms and an a priori database of chemical and biological spectral signatures to classify the contaminant.

The laser is the long pole in the tent of this problem; acceptable laser sources are not currently available. It is essential to validate the availability of a laser source with the required wavelength tunability and pulse energy characteristics. Analysis indicates that the laser must be capable of rapidly switching from one wavelength to another and emit millijoules of energy at hundreds of Hz prf. We are currently constructing a tunable ultraviolet laser based on flashlamp pumping of the newly-available Ce:LiSAF laser crystal to determine if it can be used to solve this problem. Assembly of a breadboard laser has been completed. No laser output has yet been detected, although precision alignment of the device is on hold until the student return from his temporary assignment to the CNO Strategic Studies Group in Newport, RI. If lasing can be detected, the performance characteristics of the device will be measured. Although the breadboard will not demonstrate rapid wavelength switching nor demonstrate high prf, extension to these regimes is usually a design and fabrication exercise, if the requisite pulse energy can be obtained from a rod of reasonable size and tunability can be demonstrated.

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Chemical Warfare, Biological Warfare, Detector, LIDAR

INVESTIGATIONS OF LINEAR AND NONLINEAR ACOUSTIC NOISE

Andrés Larraza, Assistant Professor
Department of Physics
Sponsors: Office of Naval Research and Naval Postgraduate School

OBJECTIVE: To perform experimental and numerical investigations of nonlinear acoustic noise in one dimension, and linear acoustic noise in a new area that we refer to as *Casimir acoustics*.

SUMMARY: Besides probing a variety of fundamental issues, our nonlinear noise research may have applications to noise generation and control, especially in regard to supersonic vehicles. An understanding may lead to techniques to actively suppress the development of shocks. The notion that acoustic noise can test, by analogy, predictions due to stochastic electrodynamics and to electromagnetic zero point field (ZPF) effects has been established recently by measurements of the force law between two rigid, parallel plates due to the radiation pressure of broadband acoustic. This measurement constitutes an acoustic analog to the Casimir effect which is the force of attraction between two closely spaced uncharged parallel conducting plates due to the ZPF. However, in contrast to the ZPF Casimir effect, band limited acoustic noise can cause the force to be attractive *or* repulsive as a function of separation between the plates. Our long-term interest in this research is to exploit linear and nonlinear acoustic noise as a system to probe fundamental physics. While nonlinear acoustic noise can probe the physics of wave systems that are driven far off equilibrium, linear acoustic noise can test, by analogy, predictions due to the ZPF which are difficult or impossible to directly verify by experiments.

PUBLICATIONS:

Larraza, A., Holmes, C.D., Susbilla, R.T., and Denardo, B., "The Force Between Two Parallel Rigid Plates Due to the Radiation Pressure of Broadband Noise: In Acoustic Casimir Effect," *Journal of the Acoustical Society of America*, Vol. 103, pp. 2267-2272, published as a Selected Research Article, 1998.

Larraza, A. and Denardo, B., "An "Acoustic Casimir Effect," *Physics Letters A*, Vol. 248, pp. 151-155, 1998.

Larraza, A., "A Demonstration Apparatus for an Acoustic Analog the Casimir Effect," *American Journal of Physics*, 1999, to appear.

Larraza, A., "Some Acoustic Analogs to Zero Point Field Effects," *Quantum Aspects of Beam Physics,* P. Chen, (ed.), World Scientific, 1998, to appear.

Simmons, T., Denardo, B., Larraza, A., and Keolian, R., "Acoustic Radiometer Demonstration," *Proceedings of the 16th International Conference on Acoustics,* Vol. 1, Patricia K. Kuhl and Lawrence A. Crum, (eds.), pp. 129-130, 1998.

Larraza, A., Holmes, C.D., Susbilla, R.T., and Denardo, B., "An Acoustic Casimir Effect," *Proceedings of the 16th International Conference on Acoustics*, Vol. 1, Patricia K. Kuhl and Lawrence A. Crum, (eds.), pp. 131-132, 1998.

Simmons, T., Denardo, B., Larraza, A., and Keolian, R., "An Acoustic Radiometer," *Journal of the Acoustical Society of America*, Vol. 103, No. 5, Pt 2, p. 2763, 1998.

Larraza, A., Holmes, C.D., Susbilla, R.T., and Denardo, B., "An Acoustic Casimir Effect," *Journal of the Acoustical Society of America*, Vol. 103, No. 5, Pt 2, p. 2763, 1998.

CONFERENCE PRESENTATION:

Larraza, A., "Some Acoustic Analogs to Electromagnetic Zero Point Field Effects: Static and Dynamic Casimir Effects," Advanced ICFA Beam Dynamics Workshop on Quantum Aspects of Beam Physics*,* Monterey, CA, 4-9 January 1998.

THESIS DIRECTED:

Chan, E.J., "Acoustic-Induced Drag on a Bubble," Master's Thesis, Naval Postgraduate School, December 1998.

DoD KEY TECHNOLOGY AREA: Other (Environmental Effects)

KEYWORDS: Nonlinear Waves, Random Waves

LINEAR AND NONLINEAR ACOUSTIC NOISE

Andrés Larraza, Assistant Professor
Bruce Denardo, Associate Professor
Department of Physics
Sponsor: Office of Naval Research

OBJECTIVE: To perform experimental, analytical, and numerical investigations of nonlinear acoustic noise in one dimension and linear acoustic noise in a new research area referred to as *Casimir acoustics*. While one-dimensional nonlinear acoustic noise probes the physics of wave systems that are driven far off equilibrium, linear acoustic noise can test, by analogy, predictions due to the quantum electromagnetic zero-point field that are difficult or impossible to directly verify by experiments.

SUMMARY: Previous results of this ongoing research involved the absorption of a sound wave due to nonlinear noise in one dimension. An experiment confirmed the prediction that the amplitude of the signal decreases with distance as a gaussian due to the signal's interaction with the noise. Current investigations focused on two effects of acoustical radiation pressure due to noise. The first effect established the notion that acoustic noise can test predictions due to stochastic electrodynamics and the electromagnetic zero-point field (ZPF). Measurements were made of the force law between two rigid, parallel plates due to the radiation pressure of broadband acoustic. This constituted an acoustic analog to the Casimir effect, which is the force of attraction between two closely spaced uncharged parallel conducting plates due to the ZPF. However, in contrast to the ZPF Casimir effect, band limited acoustic noise can cause the force to be attractive *or* repulsive as a function of separation between the plates. The second effect involved an acoustic radiometer similar to the well-known Crooke's electromagnetic radiometer, where vanes with black and white sides rotate when exposed to light of sufficient intensity. The acoustic apparatus was constructed with panes having reflective (metal) sides and absorptive (foam) sides, which rotate when exposed to intense uniform noise in an enclosure. The radiation pressure is negligible in the electromagnetic case; the vanes rotate due to thermal effects associated with the gas. In the acoustic case, however, the rotation is due to radiation pressure, as confirmed by an approximate comparison of experimental data with the theory.

PUBLICATIONS:

Larraza, Andrés and Denardo, Bruce, "An Acoustic Casimir Effect," *Physics Letters A*, Vol. 248, pp. 151-155, 1998.

Larraza, Andrés, Holmes, Christopher D., Susbilla, Robert T., and Denardo, Bruce, "The Force Between Two Parallel Rigid Plates Due to the Radiation Pressure of Broadband Noise: An Acoustic Casimir Effect," *Journal of the Acoustical Society of America,* Vol. 103, pp. 2267-2272, 1998.

Larraza, Andrés, "A Demonstration Apparatus for an Acoustic Analog of the Casimir Effect," *American Journal of Physics*, 1999, to appear.

Larraza, Andrés, "Some Acoustic Analogs to Zero Point Field Effects," *Quantum Aspects of Beam Physics,* P. Chen, (ed.), World Scientific, 1998, to appear.

Simmons, Timothy G., Denardo, Bruce, Larraza, Andrés, and Keolian, Robert, "An Acoustic Radiometer," *Journal of the Acoustical Society of America,* Vol. 103, No. 5, Pt. 2, p. 2763, 1998.

Larraza, Andrés, Holmes, Christopher D., Susbilla, Robert T., and Denardo, Bruce, "An Acoustic Casimir Effect," *Journal of the Acoustical Society of America,* Vol. 103, No. 5, Pt. 2, p. 2763, 1998.

CONFERENCE PRESENTATIONS:

Larraza, Andrés, "Some Acoustic Analogs to Electromagnetic Zero Point Field Effects: Static and Dynamic Casimir Effects," Advanced ICFA Beam Dynamics Workshop on Quantum Aspects of Beam Physics, Monterey, CA, 4-9 January 1998.

Simmons, Timothy G., Denardo, Bruce, Larraza, Andrés, and Keolian, Robert, "An Acoustic Radiometer," Acoustical Society of America, Seattle, WA, 20-26 June 1998.

Larraza, Andrés, Holmes, Christopher D., Susbilla, Robert T., and Denardo, Bruce, "An Acoustic Casimir Effect," Acoustical Society of America, Seattle, WA, 20-26 June 1998.

DoD KEY TECHNOLOGY AREAS: Other (Radiation Pressure)

KEYWORDS: Radiation Pressure, Casimir Effect, Random Waves

DEVELOPMENT OF QUANTUM DEVICE MODELS

James H. Luscombe, Associate Professor
Department of Physics
Sponsor: Naval Postgraduate School

OBJECTIVE: The goal of this program is to develop theoretical models of the electronic, magnetic and structural properties of materials and systems at the nanometer length scale. While the primary emphasis is on developing models of heterostructure quantum electron devices, there is also an interest in nano-scale magnetic systems and quantum computing. This is a continuing project.

SUMMARY: There were three separate thrusts to the research this year. (1) The effects of deliberate compositional modifications to semiconductor superlattices were examined theoretically with a view to producing high-quality Bloch oscillations, which are high-frequency electron oscillations that can produce TeraHertz radiation. (2) A new numerical method was developed to compute what are known as Wigner 3*j* and 6*j* coefficients. The Wigner coefficients are numbers that are required in models of the magnetic properties of molecular clusters containing a relatively small number (4-10) of magnetic atoms. Magnetic molecular clusters have possible applications as ultra-dense information storage systems. A classical spin approximation was developed to predict the magnetic properties of molecular clusters. Predictive models of the nuclear-magnetic-resonance (NMR) spin-lattice relaxation time in small magnetic clusters were continued to be developed. (3) Possible technologies were looked at that could be used to develop quantum computers. Of these NMR features as one possible candidate.

PUBLICATIONS:

Luban, M. and Luscombe, J.H., "Dynamical Localization of Electrons in Aperiodic Superlattices," *Physical Review B*, Vol. 57, No. 15, pp. 9043-9049, 1998.

Luscombe, J.H. and Luban, M., "Classical Heisenberg Model of Magnetic Molecular Ring Clusters: Accurate Approximates for Correlation Functions and Susceptibility," *Journal of Chemical Physics*, Vol. 108, No. 17, pp. 7266-7273, 1998.

Luscombe, J.H. and Luban, M., "Simplified Recursive Algorithm for Wigner 3*j*- and 6*j*-Symbols," *Physical Review E*, Vol. 57, No. 6, pp. 7274-7277, 1998.

Luban, M., Reynolds, J.P., and Luscombe, J.H., "Variational Tight-Binding Theory of Excitons in Compositionally Modified Semiconductor Superlattices," *Superlattices and Microstructures,* 1998, accepted.

Luscombe, J.H. and Luban, M., "Time Correlation Functions: Revealing the Dynamical Content of Thermal Equilibrium," *American Journal of Physics*, 1998, accepted.

Luscombe, J.H., "A Modern Course in Statistical Physics," *American Journal of Physics*, 1998, accepted.

Luscombe, J.H., Luban, M., and Reynolds, J.P., "Variational Tight-Binding Theory of Excitons in Compositionally Modified Semiconductor Superlattices," *Bulletin of the American Physical Society*, Vol. 43, p. 232, 1998.

Luban, M., Jang, Z., and Luscombe, J.H., "Proton Spin-Lattice Relaxation Rate for Magnetic Molecular Ring Clusters," *Bulletin of the American Physical Society*, Vol. 43, p. 218, 1998.

CONFERENCE PRESENTATIONS:

Luscombe, J.H., Luban, M. and Reynolds, J.P., "Variational Tight-Binding Theory of Excitons in Compositionally Modified Semiconductor Superlattices," Meeting of the American Physical Society, Los Angeles, CA, 16-20 March 1998.

Luban, M., Jang, Z., and Luscombe, J.H., "Proton Spin-Lattice Relaxation Rate for Magnetic Molecular Ring Clusters," Meeting of the American Physical Society, Los Angeles, CA, 16-20 March 1998.

THESES DIRECTED:

Rice, J., "Future Satellite Technology: The Role of Nanoelectronics," Master's Thesis, Naval Postgraduate School, September 1998.

Franciose, R., "Spin and Magnetism: Two Transfer Matrix Formulations of a Classical Heisenberg Ring in a Magnetic Field," Master's Thesis, Naval Postgraduate School, June 1998.

Duvall, J., "High Precision Evaluation of Wigner 3*j* and 6*j* Coefficients," Master's Thesis, Naval Postgraduate School, June 1998.

DoD KEY TECHNOLOGY AREAS: Electronics, Materials, Processes, and Structures, Modeling and Simulation

KEYWORDS: Nanoelectronics, Nanotechnology, Nanomagnetism

APPLICATION OF HYPERSPECTRAL IMAGING TO NAVAL APPLICATIONS

Richard C. Olsen, Associate Professor
Department of Physics
Sponsors: Naval Research Laboratory and Naval Postgraduate School

OBJECTIVE: To address the application of multispectral and hyperspectral imaging to Naval needs, to participate in activities utilizing HYDICE and other instruments, and to analyze data collected during these experiments.

SUMMARY: Hyperspectral image data have been acquired from experimental sensors and are being analyzed using non-literal techniques. The objectives are to identify target signatures and other features of interest in land and littoral scenes. As a particular focus, change detection was pursued.

THESES DIRECTED:

Behrens, Richard J., "Change Detection Analysis with Spectral Thermal Imagery," Master's Thesis, Naval Postgraduate School, September 1998.

Sanders, J., "Target Detection and Classification at Kernel Blitz 1997 Using Spectral Imagery," Master's Thesis, Naval Postgraduate School, December 1998.

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Remote Sensing, Targeting, Trafficability

RADIANT BRASS EXPLOITATION

Richard C. Olsen, Associate Professor
Philip L. Walker, Associate Research Professor
Department of Physics
Sponsor: Navy Tactical Exploitation of National Capabilities (TENCAP) Office

OBJECTIVE: To write a proposal and test plan to develop a method of using satellite data to predict the performance of laser designators at desert sites.

SUMMARY: The proposal was written up and submitted to TENCAP. A method of approach for this problem was devised and a test plan is being written. Funding is expected shortly.

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Environment, Lasers, Transmission

NON-IMAGING INFRARED

Richard C. Olsen, Associate Professor
Department of Physics
Sponsor: Secretary of the Air Force

OBJECTIVE: To address the application of data acquired with non-imaging infrared systems to military and civilian problems. The primary civil application is the identification and tracking of volcanic ash plumes. The initial military application is battlefield awareness, particularly bomb damage assessment (BDA).

SUMMARY: Modeling of volcanic ash plumes vs. water clouds was done. Data were acquired from several volcanic eruptions late in 1998 from the Cobra Brass sensor, which should allow for comparison to the model. Several data sets taken from military operations were acquired, which should prove helpful in the assessment of techniques for BDA.

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Remote Sensing, National Systems

ANALYSIS OF PLASMA AND FIELD DATA FROM POLAR SATELLITE PLASMA SOURCE INSTRUMENT (PSI) OPERATIONS

Richard C. Olsen, Associate Professor
Department of Physics
Sponsor: National Aeronautics and Space Administration-Marshall Space Flight Center

OBJECTIVE: Analyze charge control data from the plasma source instrument on the NASA POLAR satellite mission.

SUMMARY: The POLAR satellite was launched on 24 February 1996. The Plasma Source Instrument (PSI) was successfully operated for the first time on 15 April 1996. After a decade of effort, the plasma source performed as intended, grounding the satellite frame to the ambient plasma potential. This allowed highly sensitive measurements of the ambient plasma characteristics to be made. A survey of the plasma and field data collected during the first year of operations was made, and a special class was given at NPS in the area of spacecraft charging.

DoD KEY TECHNOLOGY AREA: Space Vehicles

KEYWORDS: Spacecraft Charging, Spacecraft-Environment Interactions

AN EXAMINATION OF 3D, BROADBAND ACOUSTIC PROPAGATION PHYSICS IN A LITTORAL OCEAN ENVIRONMENT - AN EXTENSION TO AN OFFICE OF NAVAL RESEARCH (ONR) PRIMER FIELD STUDY IN THE MID-ATLANTIC BIGHT (FY98)

Kevin B. Smith, Assistant Professor
Department of Physics
Sponsor: Office of Naval Research

OBJECTIVE: The scientific objective of this work is to study the physics and predictability of 3-D, broadband acoustic propagation upslope onto the continental shelf in the presence of strong oceanographic frontal features, specifically in the vicinity of the mid-Atlantic Bight.

SUMMARY: Special note: This funding was originally intended for the FY97 project of the same name. Due to mid-year cutbacks, my ONR sponsors withheld $16,000 until FY98. However, this project did continue under a new name with additional funding in FY98 (see the following research summary) and the summary and all products of this research are listed there.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation, Other (3-D Acoustic Propagation, Geoacoustic Inversion, Littoral Environments)

KEYWORDS: Underwater Acoustic Propagaion, Azimuthal coupling, Littoral Environments

AN EXAMINATION OF 3D ENVIRONMENTAL VARIABILITY ON BROADBAND ACOUSTIC PROPAGATION NEAR THE MID-ATLANTIC BIGHT (FY98)

Kevin B. Smith, Assistant Professor
Department of Physics
Sponsors: Office of Naval Research and Naval Postgraduate School

OBJECTIVE: To continue analysis of the PRIMER summer ’96 acoustic data and begin analysis of winter ’97 acoustic data. This analysis will primarily focus on the influence of 3-D azimuthal coupling due to bathymetric features and ocean fronts near the shelf break of the mid-Atlantic Bight, the frequency selectivity of up-slope/cross-front propagation, plane-wave beam variability through a fluctuating front with non-linear soliton wave activity, and use of various data for geoacoustic

inversion studies. The results of this analysis will provide guidance for the use of active and passive sonar systems near shelf break regions.

SUMMARY: This research was a continuation of work under the Primer initiative sponsored by the Office of Naval Research to study acoustic propagation in the region of the North Atlantic Bight off the coast of New Jersey. This region is of interest due to the combination of sloping bathymetry near the continental shelf and the strong oceanographic frontal features associated with the Gulf Stream. The general purpose of this project was to study the effects of the frontal region on acoustic propagation onto the shelf. Specifically, this work focussed on the influence of three-dimensional propagation effects and their influence on the prediction of broadband measurements in similar oceanographic regions. Studies of two-dimensional, broadband propagation were also performed to examine temporal variability of plane-wave beam arrivals. Attempts were made to invert for geoacoustic parameters and environmental effects on optimal frequency propagation.

PUBLICATIONS:

Smith, K.B., "A Three-Dimensional Propagation Algorithm Using Finite Azimuthal Aperture," *Journal of the Acoustical Society of America*, 1998, submitted.

Smith, K.B., Rojas, J.G., Miller, J.H., and Potty, G., "Geoacoustic Inversions In Shallow Water Using Direct Methods and Genetic Algorithm Techniques," *Journal of the Advanced Marine Science and Technology Society*, 1998, submitted.

Potty, G.R., Miller, J.H., Lynch, J.F., and Smith, K.B., "Tomographic Mapping of Sediments in Shallow Water," *Journal of the Acoustical Society of America*, 1998, submitted.

Smith, K.B., Rojas, J.G., Miller, J.H., and Potty, G., "Geoacoustic Inversions in Shallow Water Using Direct Methods and Genetic Algorithm Techniques," *Proceedings of Pacific Ocean Remote Sensing Conference '98*, pp. 703-707, Qingdao, China, 28-31 July 1998.

Smith, K.B., "Three-Dimensional Propagation Effects: Modeling, Observations, and Suggested Benchmark Cases," *Journal of the Acoustical Society of America*, Vol. 103, p. 2989, 1998.

CONFERENCE PRESENTATIONS:

Smith, K.B., Rojas, J.G., Miller, J.H., and Potty, G., "Geoacoustic Inversions in Shallow Water Using Direct Methods and Genetic Algorithm Techniques," Pacific Ocean Remote Sensing Conference '98, Qingdao, China, 28-31 July 1998.

Smith, K.B., "Three-Dimensional Propagation Effects: Modeling, Observations, and Suggested Benchmark Cases," Acoustical Society of America, Seattle, WA, 20-26 June 1998.

THESIS DIRECTED:

Rojas, José G., "Geoacoustic Inversion Using Direct Methods on Ambient Noise and Explosive Acoustic Data in a Shallow Water Waveguide," Master's Thesis, Naval Postgraduate School, March 1998.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Other (3-D Acoustic Propagation, Geoacoustic Inversion, Littoral Environments)

KEYWORDS: Underwater Acoustic Propagation, Azimuthal Coupling, Littoral Environments

VARIANT AUTOCORRELATION MATCHING TECHNIQUES FOR PASSIVE TRANSIENT LOCALIZATION (FY98)

Kevin B. Smith, Assistant Professor
Department of Physics
Ching-Sang Chiu, Professor
Department of Oceanography
Sponsors: Office of Naval Research and Naval Postgraduate School

OBJECTIVE: The scientific objective of this work is to study the influence of environmental and signal variability on a localization algorithm based on autocorrelation matching. Both synthetic data (to be generated) and real data will be used. Synthetic data will also be provided to other investigators testing different algorithms as well as environmental inversions from real data.

SUMMARY: Environmental variability influences on transient source localization were one focus of this study. Parameters such as sound speed, sound speed gradients, sediment layer, and water depths were altered and realistic range-dependent fluctuations caused by internal waves, solitons, or oceanographic fronts were injected. The effects of these various types of environmental mismatches on the performance of a localization algorithm were examined independently and combined to produce a realistic estimate of the resultant range-depth error. An emphasis was the quantification of the upper bounds on these environmental uncertainties for successful localization. In addition, real data was analyzed and processed through the localization algorithm. The algorithm employed to quantify localization degradation was based on autocorrelation matching (both time-domain and frequency-domain). The main purpose for using this algorithm was its simplicity. A PE model was used to establish the transfer function replicas. Copies of the synthetic transfer functions with environmental variability were provided to other investigators addressing the robustness of different localization and classification algorithms.

PUBLICATION:

Smith, K.B., Brune, J., and Chiu, C.-S., "Passive Transient Localization Using Signal Autocorrelation Matching," *Proceedings of 4th European Conference on Underwater Acoustics*, pp. 9-14, 21-25 September 1998.

CONFERENCE PRESENTATION:

Smith, K.B., Brune, J., and Chiu, C.-S., "Passive Transient Localization Using Signal Autocorrelation Matching," 4th European Conference on Underwater Acoustics, Rome, Italy, 21-25 September 1998.

THESES DIRECTED:

Correa, Arthur F. Bettega, "Shallow Water Acoustic Variability and Influences On Autocorrelation Matching Localization Algorithms," Master's Thesis, Naval Postgraduate School, December 1998.

Brune, Joachim, "Passive Transient Localization Using Autocorrelation Matching Techniques," Master's Thesis, Naval Postgraduate School, March 1998.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Sensors, Other (Localization)

KEYWORDS: Parabolic Equation Model, Autocorrelation Matching, Matched Field Processing, Transient Localization

BASIC RESEARCH IN BURSTING BUBBLES AND AEROSOL SOURCE FUNCTIONS

Donald E. Spiel, Associate Research Professor
Department of Physics
Sponsors: Office of Naval Research and National Science Foundation

OBJECTIVE: The objective of this continuing research is to determine the parameters of bursting ocean bubbles relevant to air-sea interaction and the marine boundary layer. Included are the number, size, and ejection parameters of both jet and film droplets.

SUMMARY: The parameters describing the birth of film droplets originating from bubbles bursting on sea water surfaces were measured. Results were obtained for bubble sizes D_b from 2 to 14.6 mm equivalent volume diameter. It was shown, contrary to earlier reports, that the films of all bubbles with D_b up to at least 14.6 mm burst in an orderly manner in which a hole appears at a well defined location, usually the film's edge, and propagates from there gathering up the film's mass into a toroidal ring as it progresses. This process is enabled because surface tension provides the force required to sustain the centripetal accelerations. Film drops are created when beads, of sufficient size, form along the length of the toroidal ring and surface tension is insufficient to maintain the centripetal accelerations at these accumulation points. Pieces of the ring break loose and leave the toroidal ring along paths tangential to the bubble's cap. It was shown that only bubbles larger than 2.4 mm-diameter can launch film droplets by this means and that this begins when the film has rolled up through an angle of about 31 (independent of both bubble size and (theoretically) surface tension. Film drop spray patterns recorded on MgO coated cylindrical shells surrounding the burst bubbles yield film drop numbers and trajectories. In addition, film drop size distributions, their speed of launch and the speed at which the film opens were determined as a function of bubble size. The droplet sizes measured are substantially larger than most previous estimates and, with a high probability, these droplets follow downward trajectories which lead them to impact the surface. A strong inference may be drawn that these impacts give birth to secondary droplets which are smaller than their parents and which have upward velocity components.

PUBLICATION:

Spiel, D.E., "On the Births of Film Drops From Bubbles Bursting on Seawater Surfaces," *Journal of Geophysical Research*, Vol. 103, pp.24907-24918, 1998.

DoD KEY TECHNOLOGY AREAS: Other (Environmental Effects)

KEYWORDS: Air-Sea Interaction, Jet Drops, Film Drops, Aerosols, Gas Exchange

MESOSCALE MODELING FOR ATMOSPHERIC TURBULENCE, PHASE II

Donald L. Walters, Associate Professor
Department of Physics
Douglas K. Miller
Department of Meteorology
Sponsor: Washington, D.C.

OBJECTIVE: To adapt state-of-the-art of large mesoscale numerical models, MM5 and COAMPS for computing electro-optical parameters for National Technical applications.

SUMMARY: The Mellor-Yamada 2.5 model parameterization used in the MM5 and COAMPS mesoscale models was found to be incorrect for stable atmospheres. The stable atmosphere turbulent kinetic energies were essentially zero. We have found that by altering the eddy and thermal diffusivity functions, forcing them to match recent experimental results gives optical turbulence results that agree microthermal balloon results. Comparing ETA and NOGAPS initial starting runs, it appears that usable forecasts of optical parameters out to 12-15 hours are possible. This prediction capability has a critical impact on the USAF Air Borne Laser program and other national programs.

PUBLICATIONS:

Walters, D.L. and Miller, D.K, "The Use of Mellor-Yamada 2.5 Level Mesoscale Models to Compute Turbulence in the Stable Atmosphere," *Journal of Applied Meteorology*, to be submitted.

Walters, D.L. and Miller, D.K., "Evolution of an Upper Troposphere Turbulence Event-Comparison of Observations to Numerical Simulations*," Proceedings of the Annual American Meteorological Society Meeting*, Dallas, TX, 12 January 1999.

THESIS DIRECTED:

Ambrose, C.R., "Strehl-Ratio Probabilities for Phase-Only Adaptive Optics," Master's Thesis, Naval Postgraduate School, December 1998.

DoD KEY TECHNOLOGY AREAS: Other (Adaptive Optical Systems, Imaging Systems)

KEYWORDS: Battlespace Environments, Atmospheric Turbulence, Adaptive Optics, Mesoscale Models

ATMOSPHERIC OPTICAL TURBULENCE MEASUREMENTS

Donald L. Walters, Associate Professor
Department of Physics
Sponsor: U.S. Air Force Research Laboratory

OBJECTIVE: To develop high resolution, real time sensor systems to measure the magnitude and source of severe optical degradation.

SUMMARY: The atmosphere is the primary limitation to military use of lasers and other optical systems. Adaptive optical systems are under development to compensate for phase perturbations introduced by the turbulent atmosphere but there are cost and performance limitations. The midday optical performance of the Starfire Optical range was worse than measurements made a decade ago for similar environments. Using a pair of 1-m vertical resolutions acoustic sonar systems, It was shown that a convective thermal plume forms on the south face of the mountain where the 1.6 m aperture system is located. The facility performance and the success of future planned experimental program could improve by nearly a factor of two at another location on the top on the west face of the mountain. Using the NPS data collected in January and February 1998, and collaborated by optical measurements made during March-June, 1998, a command decision was made by the primary USAF sponsor in Washington, DC to relocate the entire facility to the optimal position.

DoD KEY TECHNOLOGY AREAS: Other (Adaptive Optical Systems, Imaging Systems)

KEYWORDS: Battlespace Environments, Atmospheric Turbulence, Adaptive Optics, Sonar